An invention according to claim ~~5~~ 14 provides the piezoelectric element according to any of claims 1 to 4, in which the piezoelectric film is formed of PZT expressed by a chemical formula, $Pb(Zr_{1-x}Ti_x)O_3$ ($0.1 \leqq x \leqq 1$) or formed of a meterial mainly composed of PZT.

~~An invention according to claim 6 provides the piezoelectric~~ element according to any of claims 1 to 5, in which the piezoelectric film is formed of a solid solution of a composite oxide expressed by a chemical formula, aPZT-b [$Pb(C_{1/3}D_{2/3})O_3$ (C : alkaline-earth metals such as Mg, Zn, Ni, Mn, Co or Fe; D : V, Nb or Ta)] -c [$(Ba_{1-y}Sr_y)TiO_3$ ($0 \leqq y \leqq 1$)] ($a+b+c=1$, $0.6 \leqq a \leqq 1$, $0 \leqq b \leqq 0.4$, $0 \leqq c \leqq 0.06$) ($Pb(C_{1/3}D_{2/3})O_3$ is hereinafter referred to as "PCD", and $(Ba_{1-y}Sr_y)TiO_3$ is hereinafter ~~referred to as "BSTO")~~.

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ex. amend TMD 7/8/04

An invention according to claim 7 provides the piezoelectric element according to ~~any of claims~~ claim 1 ~~to 6~~, in which the oxide layer is 0.05 μm to 1 μm in thickness.

An invention according to claim 8 provides the piezoelectric element according to ~~any of claims~~ claim 1 ~~to 7~~, in which the piezoelectric film is 1 μm to 25 μm in thickness.

An invention according to claim 9 provides the piezoelectric element according to ~~any of claims~~ claim 1 ~~to 8~~, in which the oxide layer is not more than 10% of the piezoelectric film in thickness.

~~An invention according to claim 10 provides a process for~~ producing a piezoelectric element comprising: a first electrode forming step in which an electrode is formed on a substrate; a piezoelectric film forming step in which a piezoelectric film is formed on the electrode; and a second electrode forming step in which another electrode is formed on the piezoelectric film; wherein an oxide layer forming step in which an oxide layer is formed is performed between the first electrode forming step and the piezoelectric film ~~forming step and/or between the piezoelectric film forming step and~~

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~~the second electrode forming~~ step.

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An invention according to claim 11 provides the process according to claim 10, in which the oxide layer is formed by solution-phase method using metallic alkoxide and/or metallic salt as a starting material.

An invention according to claim 12 provides the process according to claim 10 or 11, in which the piezoelectric film is formed by solution-phase method using metallic alkoxide and/or metallic salt as a starting material.

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An invention according to claim 13 provides an ink-jet printer head provided with an ink nozzle, and in which capacity of an ink chamber communicating to the ink nozzle through an ink passage is changed by an actuator, and ink is jetted from the ink nozzle through the ink passage, wherein the piezoelectric element according to any ~~of claims 1 to 9 is used as the actuator.~~

In the piezoelectric element according to claim 1 or 2, the piezoelectric film is provided with an oxide layer which does not contain lead or an oxide layer which contains a small amount of lead, and the oxide layer is arranged on a face of the piezoelectric film, the face being in contact with the electrode. Consequently, the leakage current is decreased as compared with a piezoelectric element which is not provided with an oxide layer. It is possible to form the oxide layer by forming a film on the piezoelectric film or on the electrode, and therefore process control in the production of the piezoelectric element is relatively easy.

In the piezoelectric element according to claim 1, mechanical durability of the element is more improved, and the element is effectively prevented from breakdown or the like due to peeling of the piezoelectric element and the electrode. This is probably because, as a result of employing the oxide layer being formed of a composite

oxide expressed by a chemical formula ABO_3 or of a solid solution of one or not less than two kinds of composite oxides respectively expressed by the chemical formula ABO_3, a superior lattice matching is obtained between the oxide layer and the piezoelectric film and electrodes. In the piezoelectric element according to claim 2, a furthermore improved mechanical durability of the element is achieved. This is probably because the lattice matching is improved all the more between the oxide layer and the piezoelectric film and electrodes. In addition, in each piezoelectric element according to claims 1 and 2, mechanical durability of the element is more improved.

In the piezoelectric element according to claim 3, the piezoelectric film is provided with an oxide layer which is ferroelectric, and the oxide layer is arranged on a face of the piezoelectric film, the face being in contact with the electrode. As a result, it is possible to lower driving voltage of the piezoelectric

element.

In the piezoelectric element according to claim 4, leakage current is decreased more and, as a result, superior piezoelectric characteristics are performed.

ex. amend TMO 2/8/04

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~~In the piezoelectric element according to claim 5, the piezoelectric film is formed of PZT or formed using a material mainly composed of PZT. As a result, the piezoelectric film performs superior piezoelectric characteristics.~~

ex. amend TMO 2/8/04

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~~In the piezoelectric element according to claim 6, the piezoelectric film is formed using PZT, PCD, and BSTO as main components. As a result, not only the piezoelectric film performs superior piezoelectric characteristics, but also it is possible to change the characteristics by selecting ratio of the three components. This makes it possible to select the characteristics among a wide range of choice and is advantageous in designing the element.~~

In the piezoelectric element according to claim 7, it is possible to securely obtain the advantage of decreasing the leakage current because the oxide layer is not less than 0.05 μm in thickness, and performance as a piezoelectric element is not deteriorated because the oxide layer is not more than 1 μm in thickness.

In the piezoelectric element according to claim 8, the piezoelectric film is 1 μm to 25 μm in thickness. As a result, there is no problem that effective vibration is not achieved by the element due to excessively thin piezoelectric film and deficient driving force and that a large driving voltage is required for displacement of the element due to excessively thick piezoelectric film.

In the piezoelectric element according to claim 9, the oxide layer is not more than 10% of the piezoelectric film in thickness, and therefore the piezoelectric characteristics to serve as a piezoelectric element are not deteriorated. When the oxide layer

is excessively thick, ratio of the piezoelectric film to the whole piezoelectric element is smaller, and this causes deterioration in characteristics of the piezoelectric element such as increase in driving voltage otherwise decrease in displacement amplitude of the element. However, such deterioration does not occur when the oxide layer is not more than 10% of the piezoelectric film in thickness.

Ex. amend 7/8/04 TMD

~~In the process for producing the piezoelectric element~~ according to claims 10 to 12, the piezoelectric element according to claim 1 is obtained through a relatively simple process.

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The ink-jet printer head according to claim 13 is provided with the piezoelectric element having the foregoing characteristics of each invention according to claims 1 to 9 as the actuator. As ~~a result, it is possible to attain improvement in performance.~~

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an embodiment according to the present invention and is a partially enlarged sectional view of a piezoelectric element.

Fig. 2 is a vertical sectional view of an ink-jet printer head in which the piezoelectric element shown in Fig. 1 is used as an actuator, and a part of the ink-jet printer head is enlargedly and schematically shown.

Fig. 3 is a view showing I-V characteristics of each of the piezoelectric element obtained in Example 3 and that obtained in Comparative Example 1.

Fig. 4 is a view showing I-V characteristics of each of the piezoelectric element obtained in Example 24 and that obtained in Comparative Example 4.

Fig. 5 is a vertical sectional view of an ink-jet printer head in which a conventional piezoelectric element is used as an actuator, and a part of the ink-jet printer head is enlargedly and schematically